Computer Simulation in AEC and its Future Development

Jonathan Jingsheng Shi, Associate Professor
Department of Building and Construction
City University of Hong Kong
Tat Chee Ave, Hong Kong

Introduction

Unlike architectural and engineering designs that are carried in house, construction has to be performed on an actual site. It is therefore impossible to achieve a full AEC integration on computers. This may render the situation that AEC technologies focus on architectural and engineering design perspectives (Zamanian and Pittman 1999), and construction perspective is often neglected (Mckinney and Fischer 1998). From construction perspective, the AEC integration will enable the client to experiment and visualize the construction process of the designed project on a computer so as to get an accurate estimate of the construction duration and cost for developing the project. Because components or parts of a building are the entities that designers deal with in design and they are also the physical components to be constructed by contractors, product-modeling approach has been researched and accepted as the starting point for integrating construction (Tolman 1999). Luiten et al (1998) extended this approach to relate product, activity and resource information for generating a construction time schedule based on 4D-CAD (CAD plus time) models.

Traditionally, detailed construction resources and methods are not considered at the preliminary planning stage, but are left to contractors to decide at the construction stage. Such planning approach has caused many problems in the industry. For instance, the original plans may be too expensive, unrealistic, or even not constructable. Detailed construction issues must be integrated into the early design stage to avoid these problems like duration and cost overruns in the industry.

Since the development of CYCLONE by Halpin (1977), construction process simulation has been proven to be an effective tool for planning and improving the performance of construction processes with many successful applications. Comparing with traditional scheduling and planning methods (e.g. CPM), computer simulation has the following advantages (Halpin 1993):

- Modeling resources: Many important characteristics of resources can only be modeled through simulation technique, including: 1) active role of resources in performing construction operations; 2) relationship between the actual construction progress and the involved resources, such as different productivity of equipment capacity; 3) resources shared simultaneously by multiple activities.

- Dynamics: A construction operation is a dynamic process involving the dynamic interactions between activities/processes and between activities and

resources. No any other tool is able to model the dynamic behavior of construction operations.

- Randomness: A construction operation is affected by many random factors such as operating status of equipment and weather conditions. Only the simulation technique enables these considerations to be incorporated into construction planning.

Because of these important features, computer simulation provides an effective tool for integrating detailed construction process information into design processes to enable the client and other involved parties to have a better understanding about the construction of the project before it starts.

Construction simulation and its future development

Despite these indisputable advantages, construction simulation suffers some serious drawbacks. First of all, it is difficult to use so that simulation is still treated as the last resort among various planning tools. Moreover, process-based simulation results should be integrated to a higher project level. The difficulties involved in using simulation in construction have been widely experienced by all levels of users from academics to construction engineers. It requires technical training to grasp the needed knowledge for conducting simulation. Moreover, it requires extensive hand-on experience to master the skills. The learning process can be months or even years long. It has been recognized that the difficulty-in-use has greatly hindered the application of simulation in the construction industry (Shi and AbouRizk 1997). Although it was concluded in a workshop sponsored by the National Science Foundation a decade ago that more research needs to be done to make simulation an ease-of-use tool for practitioners, no substantial advancement has been made.

Computer simulation is the process of designing a mathematical-logical model of a real world system and experimenting with the model on a computer. Three phases can be identified in using simulation to resolve a real world problem as shown in Figure 1: modeling, experimentation and optimization.

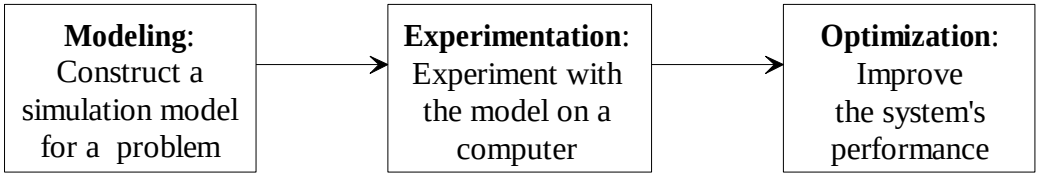

Figure 1 Three phases of computer simulation

Modeling is the process to describe a stated problem in terms acceptable to a computing system. Experimentation is to execute the simulation model so that the system's operations can be duplicated on a computer and the system's dynamic operating behaviors can be observed. Simulation optimization is the process of searching a feasible or optimum solution after analyzing the simulation outputs.

To accomplish the full functionality if simulation in an AEC environment, a lot of research efforts are needed. The following points reflect the author's personal views.

1. New method for modeling a construction process and project

Construction simulation modeling employs various modeling elements (e.g. queue, normal, and combined nodes in CYCLONE) to represent a construction process. One of the major difficulties in using computer simulation involves in modeling because modeling elements are foreign to construction practitioners. New effective and easy-to-use modeling methods have to be explored.

Activities represent identifiable construction operations. Conventional construction scheduling and planning methods, such as CPM, use activities as the planning basis. ABC is an activity-based construction modeling and simulation method developed in recent years by the author (Shi 1999). ABC employs one single element, activity, to model a general construction process. Experimenting with the ABC model in the ABC simulation environment, the random and dynamic features of the process can be simulated and displayed on a computer screen through the developed simulation algorithm and iconic animation function. In summary, ABC's modeling approach is similar to CPM, but ABC carries all features in computer simulation.

Moreover, a project consists of many processes and a process may also contain sub-processes. Research is needed to explore how process-based simulation results can be integrated to the project level so that the entire project can be experimented on a computer with site conditions, resource and construction method information.

2. Animation of construction progress

Conventional animation seeks to re-create “life” through the artistic skills of an animator who transforms his or her observations, experiences, and intuition into believable objects. Visual reality technology creates a 3-dimentional environment to allow animation close to the real world. However, the complexity of re-creating real live images (e.g. a construction site) as well as the difficulties of graphically updating complex changing information in the animation environment have led to limited capabilities of such animation tools. Moreover, cost and time considerations also restrain the application of this type of animation for construction simulation. The purpose of animation is to enable the user to visualize the dynamic interactions during the real construction process. Comparably, a 2-D iconic animation provides an alternative for achieving the objective with much less effort needed.

3. Automation and integration

Above mentioned three phases of simulation modeling, experimentation, and optimization should be automated so that various construction scenarios can be experimented and the optimum solution of the project can be automatically identified based on user-specified project objectives. Moreover, simulation provides only one of the many functions needed in an AEC environment. It requires deign information and

also generates information. Simulation has to be integrated to the overall AEC environment.

Conclusion

Simulation provides the features to experiment the construction process of a project under design on computers so that the client can get a more accurate picture of the construction duration, cost, and other key concerned issues. It should be incorporated into any AEC environment. In the mean time, some technical problems in construction simulation must be solved in order to achieve a successful integration between design and construction.

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About the Author

Dr. Jonathan Shi obtained his Ph.D. in Civil Engineering from the University of Alberta in 1995. Since then, he has been working at City University of Hong Kong, and will join Illinois Institute of Technology as an Associate Professor in August. Dr. Shi started his first construction simulation project in 1984, and has been researching in this area for the last fifteen years. From the direct experience of applied research and consulting services, he realizes the advantages of simulation and visions that simulation will play a more important role in the construction industry. Dr. Shi attempted to integrate design information to the automated construction simulation system.